Using Hydrodynamic Models to Interpret Remote Sensing Images of the Sea Surface

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LONG-TERM GOALS

The long-term goals are to develop methodologies for determining beach topography in the nearshore, using various types of remotely-sensed images of the water surface as input. We are particularly interested in regions such as the surfzone, where linear theory provides a poor description of the behavior of individual wave crests.

OBJECTIVES

The objectives of the present project are to:

(1) Develop a synthetic data set, based on Boussinesq model predictions, representing a number of cases of waves propagating over characteristic nearshore bathymetries.

(2) Compare model results to available SandyDuck data.

(3) Study the feasibility of solving the inverse problem for bathymetry from measured surface data, using a wave model to determine wave phase speeds and wave-induced height and velocity fields.

APPROACH

Much of the effort in the first year of the project has been concentrated on enhancing the Boussinesq model to the point where it is capable of providing a robust description of surfzone phenomena. Special attention has been paid to problems associated with describing wave breaking and the shoreline runup. The resulting model has been extensively tested. At present, we have started the process of building up the synthetic data set, which will be used to test simple inversion schemes based on linear theory as well as more involved schemes using the nonlinear model as the means for time-stepping solutions.

The anticipated INSAR data set from the SandyDuck experiment was not available, and we have attempted to utilize, instead, other available data sets based on scanning surface radars. Work on inversion techniques has gone forward based on synthetic data sets.

WORK COMPLETED

Various enhancements to the Boussinesq model code have been made. A refinement of the eddy-viscosity algorithm for wave breaking and the development of an accurate beach-slot formulation have improved the model's accuracy in predicting surfzone wave processes. We have also developed an internal wave-source algorithm which generates a wave field which propagates entirely in the incident-wave direction, eliminating the need for much of the extensive sponge layer regions needed at the offshore boundary of many models with symmetric internal sources (Chawla and Kirby, 1998).

A version of the model code in Fortran 90 with HPF extensions has been developed for application on parallel computers, and has been tested on an 8 node PC cluster. Typical speedups relative to a single processor application are typically in the range of 5 - 5.5 times. This model code is ready for testing on massively parallel machines such as the Cray T3.

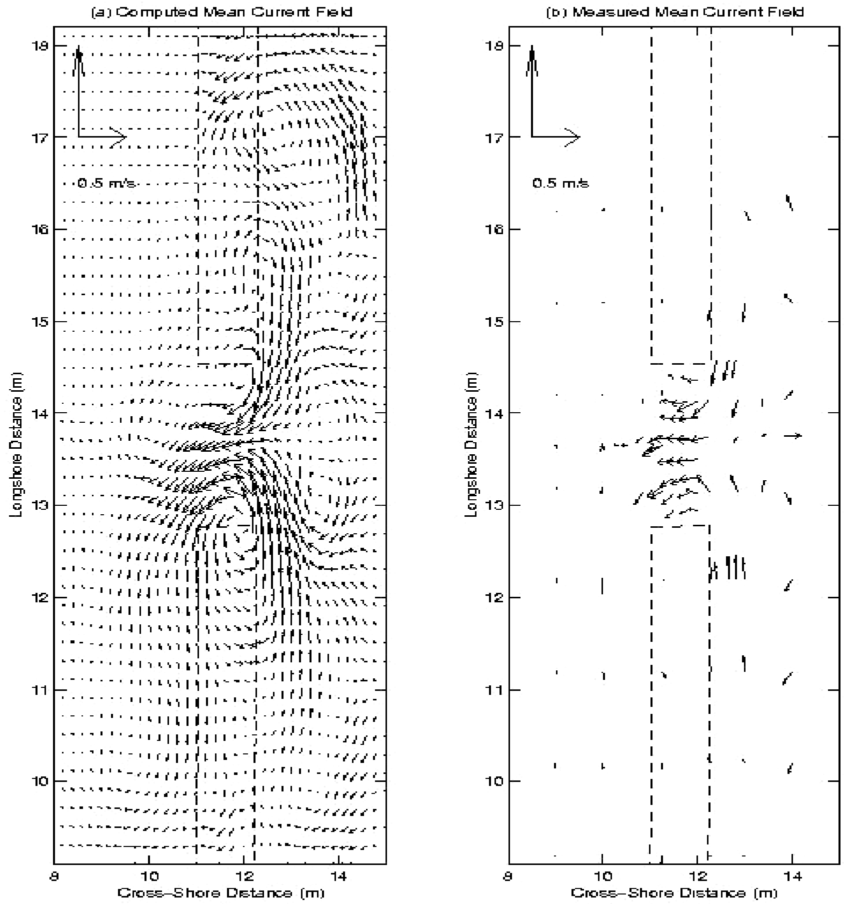
Various iterative approaches to the solution of the depth inversion problem using the fully nonlinear model equations have been investigated, and a rapid convergence to the correct answer has been obtained for cases where the entire dynamical input (surface and velocity) is specified. We are presently investigating the case where the data set is incomplete.

RESULTS

The refinement of the Boussinesq model's algorithms for shoreline runup and wave breaking have lead to a model which performs well in a number of situations, as judged by comparison to laboratory data (Chen et al 1998a,b; Kennedy et al 1998). The following figure illustrates a comparison between a time-averages velocity field of a rip current measured in the lab (right) and as obtained from the Boussinesq model Funwave (left).

Two inversion methods have been examined to determine bathymetry from surface elevation information (an image or a pair of images of the water surface), and are described in Dalrymple et al (1998). The first method examined the ability of linear dispersion relationship model to determine bathymetry in cases with refraction, diffraction, and wave nonlinearity, and the second method is based on the lagged correlation method (and several images), which is more generally useful for application.

The linear dispersion relationship method is reasonably robust in determining water depth in the presence of nonlinearity and noise, provided that the wave period is accurately known. The second method, based on cross-correlations and a maximum entropy method, is almost insensitive to noise and provides a reasonable method for field applications.



IMPACT/APPLICATIONS

The work on the project to date has led to a more robust version of the Boussinesq model code which is capable of accurately representing wave shoaling, decay and runup as well as wave- induced circulation, in comparison to laboratory data. The model code is available to the research and engineering community.

TRANSITIONS

The work on this project is closely related to an ongoing Army Research Office project (Kirby and Dalrymple, P.I.'s) which is addressing the development of a curvilinear version of the Boussinesq model code for application to complex coastal regions. The model formulation from this project serves as the basis for the ARO project developments, and the resulting ARO code will allow for various optimizations in model applications which are not presently available to users of the existing code, including the ability to specify a variable cross-shore grid spacing. The resulting curvilinear grid code will also be useful in interpreting remote-sensing imagery of complex coastal areas.

REFERENCES

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